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FUNDAMENTAL PRINCIPLES OF TECHNICAL AND ECONOMIC CALCULATIONS IN POWER ENGINEERING

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FUNDAMENTAL PRINCIPLES OF TECHNICAL AND ECONOMIC CALCULATIONS IN POWER ENGINEERING

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1. The purpose of technological and economic calculations is the selection of the most economical cariant for the solution of a certain problem in order to satisfy various national economic requirements.

The cost of production does not give a complete conception of its economy /efficiency/, since it does not take into account labor expenditures for the manufacture of the product on behalf of society. Up to the present time, there does not yet exist a generally accepted method for determining the cost of production.

The economy of the variant must be evaluated by taking into account initial capital investments as well as current expenditures. Therefore, for a comparative cost evaluation of variants, we must now use the method of time, during which the product pays for itself, which measures capital expenditures together with future manufacturing expenditures, i.e., with the cost of output.

Cost indices are the decisive factor in the technical and economic evaluation of variants. The qualitative properties of all the variants that are being compared must be evaluated, as far as possible, from the cost angle. Only if the latter is not feasible, will it be necessary to resort to natural indices, of one type or another, for a supplementary qualitative evaluation of the variants.

2. In evaluating the comparative economy /efficiency/ of two or more variants, each of the variants under comparison must be analyzed, proceeding from the conditions of its maximal economy.

The variants under comparison must be compared with-

in the given system of power installations, with the premise of uniform power output by each of the variants.

3. The method of time, during which the installation pays for itself, consists of the comparison of the difference in capital investments by variants with cost economy according to the formula

$$T = \frac{K_2 - K_1}{C_1 - C_2}, \qquad (1)$$

where K_1 and C_1 are the capital investments and the cost of annual output, respectively, (annual production expenditures) of the first variant;
K_2 and C_2 - signify the same for the second variant.

The time arrived at, during which the installation pays for itself - T, expressed in years, is compared with the standard time during which the installation is amortized - T_n:

$$T \gtrless T_n.$$

If T equals T_n, then the variants under comparison are of equal value;

if $T < T_n$, then the second variant (K_2 and C_2) is more economical, i.e., it involves larger capital investments and smaller cost of production;

if $T > T_n$ the variant with smaller capital investments, K_1, and larger cost of production, C_1, will be more economical.

It is possible to intorduce the value of the standard amortization period T_n directly into the calculation formula

$$C_1 + \frac{1}{T_n} K_1 \gtrless C_2 + \frac{1}{T_n} K_2. \qquad (2)$$

Then that variant will be regarded as economical which has a smaller total value, i.e., conforms to the condition

$$C + \frac{1}{T_n} K = \text{Minimum} \qquad (3)$$

The formula for the calculation of the method of time, during which the product pays for itself, according to expression (1) can be utilized only for a comparison of variants in pairs. Formula (3) can be utilized for a comparison of any number of variants and, therefore, is more convenient in a number of cases.

The inverse value to the standard amortization time is designated as the standard effectiveness coefficient and is expressed by P_n. Formula (3), then, will assume

the following form:

$$3 = C + \frac{1}{T_n} K = C + p_n K = \text{minimum} \qquad (4)$$

This value, further on, will be designated as calculated expenditures.

4. The value of the standard amortization period (or standard effectiveness coefficient) must be taken as uniform for all calculations in the field of power engineering and as equal, over the short term, to eight years (standard effectiveness coefficient - 12.5 percent).

5. In determining the calculation of expenditures according to formula (4), the following must be taken into account:

a) Cost C (annual production expenditures) must comprise: write-offs for amortization, raw material expenditures, expenditures of fuel, power and other material values, direct wages of workers and employees, current repair expenditures, general shop and general plant expenditures, money spent on social insurance, overhead, etc.

b) Capital investments K must comprise: cost of the basic projected object K_{basic}, turnover funds K_{turn} and, in certain cases, contiguous capital investments K_{cont}.

6. The determination of component expenditures must be carried out by means of comparable prices. The cost of installation for power plants, as well as expenditures of raw material, fuel, power, and other materials, must be taken into account in accordance with their listed sales prices.

At the existing system of price formations, however, prices do not fully reflect their national economic value, and a utilization of prices in technical and economic calculations may lead to considerable errors, distorting the results. Therefore, in cases where one individual type of expenditure exerts a visible influence on the results of comparisons, list prices should be substituted by the cost of the production engaged in and contiguous capital investments should be taken into account in the sum of capital investments. (At calculations according to price lists, contiguous capital investments should be left out of consideration.)

7. Contiguous capital investments (K_{cont}) constitute capital investments in a branch of industry, the output of which is utilized as technological raw material in the projected object. Contiguous capital investments should be determined only for industry branches, the output of which is of considerable importance within the framework of capital investments or of production cost of

the enterprise contemplated. For the latter industry branches, in turn, capital investments in other branches are required that are connected with the former. However, as a rule, this cannot be computed with a sufficient degree of exactitude.

In technological and economic calculations in the field of power engineering, contiguous capital investments, as a rule, must be transferred to /accounted for in/ the fuel industry and the transportation of fuel and power to the consumer. In doing so, current expenditures must be taken into account in accordance with the cost of fuel and of transportation.

8. In determining the value of capital investments one must take into consideration that, apart from capital investments in basic production objects (K_{basic}), investments for setting up current assets may be called for (K_{ca}) in the form of indispensable stocks of raw materials, other materials, fuel, semi-manufactured products and other objects that make work performance possible.

The volume of funds required for current operations must be determined by taking into account the speed of their turnover.

9. Amortization write-offs take into account the original cost of the object less its current value (cost of the values remaining after discontinuation of utilization of the object) and the expenditures for capital repairs. The term of service of the object, at determining amortization write-offs, must be established by taking into account its physical and moral wear and tear /deterioration/.

Amortization write-offs are computed in certain percentages of the original cost of the object. In these computations one must abide by the standards of amortization write-offs for individual types of equipment, set up by taking into account the length of service and the intensity of its utilization. In working out amortization standards one should take into consideration that amortization write-offs prior to the moment of their utilization in a given enterprise can be utilized for an expanded reproduction in other sectors of the national economy.

10. A computation of expenditures for electric power, in determining the cost of production, must be carried out by taking into account the expenses for its transmission over the networks and, differentiated, by taking account the fluctuation in its load diagram of consumers (T_{max}) and the degree of one's /its/ participation in the maximum load of the system (k_m).

If the tariff does not correspond to the require-

ments, it is possible to determine the expenditures for one kilowatt hour of needed electric power by the following formula:

$$З_э = a + \frac{k_н k_р}{T_{max.}}(b + p_н K_c), \qquad (5)$$

where a are the variable expenditures of the electric power system with reference to one kilowatt hour of electric power output (approximately equal to the fuel component);
where b are the constant annual expenditures of the electric power system with reference to one kilowatt of the established power of the system (approximately equal to all the expenditures of the electric power system without the expenditures for fuel);
where k_p is the coefficient showing the power reserve of the system (k_p = 1.15 - 1.20);
where K_c is the cost of one kilowatt of the established power of the electric power system.

11. The cost of electric power that ensures coverage of losses should also be taken into account, as should be the expenditures for usefully employed electric power.

12. If, in comparing the variants, capital expenditures take place at different times, the varients should be compared with reference to the volume of said capital expenditures. The expenditures of earlier years K_o with reference to the moment of comparison must be applied according to the standard coefficient of effectiveness of capital investments p_n proceeding from the compound interest formula:

$$K = K_0 \cdot (1 + p_н)^t, \qquad (6)$$

where K represents the said expenditures over t years.

The terms of installation of the objects and the distribution of capital investments by years of construction are computed by a summation of all the annual volumes of capital investments reduced to the moment of the termination of construction:

$$K = K_1(1 + p_н)^{t-1} + K_2(1 + p_н)^{t-2} + \dots + K_{t-1}(1 + p_н) + K_t, \qquad (7)$$

where K is the sum total of the stated capital investments;

where $K_1, K_2, \ldots K_{t-1}, K_t$ are the capital investments of the corresponding construction year,

t is the construction period of the object

The sum total of said capital investments K, arrived at by the variants, determines the calculated cost of constructing the object and is utilized in further calculations for determining the economy /efficiency/ of the given object by formulas (1) and (4).

13. At a change of the productive capacity of the object as time passes, for instance, at an increase of the output by it, at a growth of the power load of the electric transmission line, etc., the variants under comparison may vary with respect to the volume and order of realization of capital investments as well as with respect to the volume of annual production expenditures by individual periods of utilization.

In that case, it is necessary to reduce the time-varying capital investments and annual expenditures to a comparable form, recomputing them as per the moment of completion of the entire object according to the established standard of national economic effectiveness of capital investments p_n, proceeding from the formula of compound interest.

14. A determination of the economic expediency of making supplementary capital investments for repairs, modernization, or substitution of the old installation by a new one should preferably be made by way of comparing the expenditures, computed according to each variant and reduced to an identical power effect.

Expenditures in conducting work with the old installation are

$$З_{ст} = C_{ст} + p_н K_{ст} \qquad (8)$$

Expenditures after the completion of repairs or modernization are

$$З_р = C_р + p_н (K_{ст} + K_р). \qquad (9)$$

Expenditures after exchange of the old installation for a new one are

$$З_н = C_н + p_н (K_{ст} + K_н - K_л). \qquad (10)$$

where Cold, C_p, C_n signify the cost of annual output of

the relative variants;

K_{old} is the re-employable cost of the not-worn-out part of the old installation;

K_p, K_n is the supplementary capital investment of the corresponding variants;

K_l is the liquid [current-asset] cost.

If the expenditures defined by formula (9) or (10) will be less than the expenditures given in formula (8), then the effectuation of one or another measure should be considered as economically expedient.

Examples of Calculations

Example No. 1 (for point 12).

The requirement is to compare two construction variants of one and the same object, to be realized in different periods and in a different order of capital investments.

<u>According to the first variant</u> of the execution of the execution of the work, the total time of its completion t is determined at four years. The estimated cost of construction is 20 million rubles. The order of investments is 5 million rubles annually.

<u>According to the second variant</u> of the execution of the work, construction starts one year later and is completed in three years. The estimated cost of construction is 21 million rubles. The order of investment of the funds by year is as follows: four, seven and ten million rubles.

The effectiveness coefficient is p_n = 12.5 percent (the time during which the installation will be paid for is eight years).

The above capital investments, by the time the installation is put into operation (calculated cost of the object), determined according to formula (7), will be:

<u>First variant</u>

$$K = K_1(1+p_n)^{t-1} + K_2(1+p_n)^{t-2} + K_3(1+p_n)^{t-3} + K_4 = 5(1+0{,}125)^3 + 5(1+0{,}125)^2 + 5(1+0{,}125) + 5 = 24{,}07 \text{ million ruble}$$

<u>Second variant</u>

$$K = K_1(1+p_n)^{t-1} + K_2(1+p_n)^{t-2} + K_3 = 4(1+0{,}125)^2 + 7(1+0{,}125) + 10 = 22{,}94 \text{ million ruble}$$

The second variant appears to be more economical despite the fact that its estimated cost is higher by 1 million rubles.

Example No. 2 (for point 3).

The requirement is to compare the economy of two variants of one and the same object differing from each other as to capital investments and utilization expenditures.

In the first variant (reduced to the time the installation is put into operation), capital investments are equal to 10 million rubles, and annual utilization expenditures (computed by including amortization write-offs) are 1 million rubles.

Capital investments according to the second variant are equal to five million rubles, but annual utilization expenditures come to 2 million rubles.

The standard amortization period is eight years (standard effectiveness coefficient - 12.5 percent).

According to formula (1), the period of time required by the installation to pay for itself is:

$$T = \frac{K_1 - K_2}{C_2 - C_1} = \frac{10-5}{2-1} = 5 \text{ years}$$

A comparison of the time required to pay for itself with the standard time of amortization points to the economy of the first variant.

The same result is arrived at by utilizing formula (4).

The calculated expenditures of the first variant are

$$З = C + p_н K = 1 + 0{,}125 \cdot 10 = 2{,}25 \text{ million rubles}$$

The calculated expenditures of the second variant are

$$З = C + p_н K = 2 + 0{,}125 \cdot 5 = 2{,}625 \text{ million rubles}$$

Example No. 3 (for point 3).

The requirement is to compare the economy of four variants of one and the same object, the capital investments and annual expenditures for which amount to:

$$\begin{array}{llll}
K_1 = 2{,}0 & \text{million rubles} & C_1 = 1{,}8 & \text{million rubles} \\
K_2 = 3{,}0 & \text{"} & C_2 = 1{,}2 & \text{"} \\
K_3 = 5{,}0 & \text{"} & C_3 = 0{,}8 & \text{"} \\
K_4 = 7{,}5 & \text{"} & C_4 = 0{,}6 & \text{"}
\end{array}$$

The standard amortization time is eight years (standard effectiveness coefficient - 12.5 percent).

At a larger number of variants, it is more convenient to utilize formula (4) for calculations. The results of determining the calculated expenditures will be as follows:

$$З_1 = C_1 + p_н K_1 = 1,8 + 0,125 \cdot 2,0 = 2,05 \text{ million rubles}$$
$$З_2 = C_2 + p_н K_2 = 1,2 + 0,125 \cdot 3,0 = 1,57 \text{ "}$$
$$З_3 = C_3 + p_н K_3 = 0,8 + 0,125 \cdot 5,0 = 1,42 \text{ "}$$
$$З_4 = C_4 + p_н K_4 = 0,6 + 0,125 \cdot 7,5 = 1,54 \text{ "}$$

The most economical variant is the third.

When applying formula (1), the calculations will be more complex. Here variants can be compared only in pairs.

This is a comparison of the first and second variant:

$$T_{1-2} = \frac{K_2 - K_1}{C_1 - C_2} = \frac{3-2}{1,8-1,2} = 1,66 \text{ year} < T_н = 8 \text{ years}$$

The second variant is more economical.

This is a comparison of the second and third variant:

$$T_{2-3} = \frac{K_3 - K_2}{C_2 - C_3} = \frac{5-3}{1,2-0,8} = 5 \text{ years} < 8 \text{ years}$$

The third variant is more economical.

This is a comparison of the third and fourth variant:

$$T_{3-4} = \frac{K_4 - K_3}{C_3 - C_4} = \frac{7,5-5}{0,8-0,6} = 12,5 \text{ years} > 8 \text{ years}$$

The third variant is more economical.

The results of the calculations have, of course, coincided, but it is much more convenient to carry out calculations by means of formula (4).

Example No. 4 (for point 13).

The requirement is to compare two variants of the construction of the object that vary, as to tome, in their volume of capital investments and of annual production expenditures. It is known that after t years the productive power of this object must be doubled.

Two variants are available for the solution of this problem.

First variant. For the beginning, the utilization of the object is undertaken only in a volume required for putting into operation the potential necessary during the first period. Toward the beginning of the second period (after t years), new structures are added to the object for its expansion to a volume required for putting into operation the supplementary potential.

Second variant. The object is constructed from the start for its entire productive power. Basic capital investments in the object are made at the start of the first period of utilization; at the start of the second period of utilization, only minor supplementary capital investments are necessary.

Let us designate the capital investments made at the start of the utilization of the object according to the first variant as K_1', and according to the second variant as K_2'. Capital investments made prior to the start of the second period of utilization will be designated as K_1'' and K_2''. The corresponding utilization expenditures during the first period of utilization will be designated as C_1' and C_2', and during the second period of utilization as C_1'' and C_2''.

The variants should be compared by including in the second period a determination of the calculated annual expenditures during the second period of utilization by taking into account all the previously incurred one-time and annual expenditures.

For the case on hand, the calculated annual expenditures of the second period are determined by variants by means of the following formula:

$$З_1'' = C_1'' + p_н(K_1' + K_1'');$$

$$З_2'' = C_2'' + p_н\left\{K_2' + K_2'' + \left[(K_2' - K_1') + \frac{C_2' - C_1'}{p_н}\right]\cdot\left[(1 + p_н)^t - 1\right]\right\}.$$

The smaller volume of expenditures points to the most economical variant.

Let us assume that the variants are characterized by the following data:

First variant

$K_1' = 10$ million rubles $\quad K_1'' = 10$ million rubles

$C_1' = 1$ " $\quad C_1'' = 2$ "

Second variant

$$K_2' = 17 \text{ млн. руб.}; \; K_2'' = 1 \text{ million rubles}$$
$$C_2' = 1{,}1 \text{ млн. руб.}; \; C_2'' = 1{,}9 \text{ million rubles}$$

The increase of the object's potential must be accomplished in five years.

A determination of the calculated expenditures $p_n = 0.125$ produces the following result

First variant

$$З_1'' = 2{,}0 + 0{,}125 \cdot (10 + 10) = 4{,}5 \text{ million rubles}$$

Second variant

$$З_2'' = 1{,}9 + 0{,}125 \left\{ 17 + 1 + \left[(17 - 10) + \frac{1{,}1 - 1}{0{,}125} \right] \times \right.$$
$$\left. \times \left[(1 + 0{,}125)^5 - 1 \right] \right\} = 4{,}92 \text{ million rubles}$$

The first variant proves to be suitable from the economy angle despite the fact that it requires more over-all capital investments and greater production expenditures during the second period of utilization.

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